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Federal Plan for Marine Meteorological Services

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FEDERAL PLAN
FOR
MARINE METEOROLOGICAL SERVICES

FISCAL YEARS 1968 - 1972

U. S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
FEDERAL COORDINATOR FOR METEOROLOGICAL
SERVICES AND SUPPORTING RESEARCH

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FOREWORD

This Federal Plan for Marine Meteorological Services focuses on the needs of an increasingly marine-oriented general public and the needs of maritime industry, commerce, and national defense for specialized meteorological support. It is directed toward providing improved services to these users in the time period FY-68 through 72 and, in addition, clarifies the relationship between civil and military programs.

This Federal Plan, one in a series of plans being prepared by the Office of the Federal Coordinator for Meteorological Services and Supporting Research to describe present and planned services in support of specialized user groups, has been prepared in response to Bureau of the Budget Circular A-62 and in accord with the objectives stated by the National Council on Marine Resources and Engineering Development. Federal agencies concerned with marine meteorology have participated in preparing this plan, specifically the Navy, Coast Guard, National Aeronautics and Space Administration, National Science Foundation and Environmental Science Services Administration.

In consonance with the responsibilities of the Federal Coordinator, this Plan is limited to Federal meteorological programs and does not include oceanographic or other related programs. In certain instances, oceanographic programs are referenced to give a better perspective in the often closely interrelated meteorological and physical oceanographic efforts. Programs in the latter area are included in the Federal Plan for Marine Physical Environmental Prediction.

Robert M. White
Federal Coordinator for Meteorological
Services and Supporting Research

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INTRODUCTION

To mobilize the Nation's marine science activities, the Marine Resources and Engineering Development Act of 1966 [1] declares it to be the policy of the United States "to develop, encourage, and maintain a coordinated, comprehensive and long-range national program in marine science for the benefit of mankind to assist in protection of health and property, enhancement of commerce, transportation, and national security, rehabilitation of our commercial fisheries, and increased utilization of these and other resources."

Increasing national interest in the sea and its potential resources can be measured in part by the surge in marine-related developments and activities on the part of industry and commerce during recent years. For example, during the period 1960-1964, United States domestic production of crude oil from offshore wells increased by 72 percent and in 1964 accounted for 7.3 percent of total domestic output. Natural gas production from offshore wells increased almost 100 percent during the same period and year; metals and minerals obtained from oceans bordering the United States (exclusive of sand and gravel) had an estimated value of $104,000,000 -- an increase of more than 50 percent over 1960.

In the 10-year period 1953-1963, national waterborne commerce increased from 374.4 to 554.7 million short tons. In 1963, more than 1,600,000 passengers traveled by sea between the United States and foreign shores, 20 percent of them in United States flag ships. Expenditures for port development during this same year amounted to $213,000,000. In 1965, American commercial fishing vessels accounted for about 6 billion pounds -- more than 5 percent of the world's seafood catch.

An expansion in public and private use of the marine environment for recreational purposes has accompanied this rapid growth in commercial and industrial activity. Salt-water sport fishing attracted almost 8,000,000 fishermen in 1964, involving expenditures estimated at $760,000,000. There are approximately 8,000,000 small-boat owners in the United States at the present time, plus 1,000,000 surfers, and 3,000,000 skin divers. With the growth in rapid transportation facilities and an increasingly affluent society, participation in marine recreational activities is no longer limited to those living adjacent to the sea or near inland lakes and waterways but now includes a broad segment of our population.

The vulnerability of individuals engaged in marine activities or living near the sea is all too apparent. During FY-64, weather was the primary cause or a contributing factor in damages to high-seas shipping amounting to $33,000,000, with 26 lives lost. In March 1962, a severe slow-moving coastal storm caused approximately $200,000,000 damage to the eastern seaboard. During 1964, 216 lives were lost in small boating accidents in which weather was a factor.

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1 Public Law, Section 2(a), 89-454, 89th Congress, S.944, June 17, 1966

More than 900 active Naval ships (plus more than 300 Coast Guard vessels) and thousands of military aircraft operate within the marine environment. They, and the many major defense installations located in coastal areas, require marine meteorological services to carry out their national security missions.

Adequate Marine Meteorological Services*, together with appropriate oceanographic support, can reduce these losses in life and property, promote the safety and efficiency of marine operations, and contribute to a fuller realization of the potential of the sea. To insure that these services keep pace with the growth and needs of users, a coordinated Federal program is necessary so that:

- Existing requirements for services are identified and satisfied.
- Demands for new services are met most effectively and economically.
- New technology is introduced to improve the accuracy and timeliness of services.
- An integrated, effective Federal system is developed in response to the objective of exploring, using, and conserving the Nation's marine resources.

ROLE OF FEDERAL AGENCIES

Though numerous Federal departments and agencies are users of Marine Meteorological Services, three have specific statutory responsibilities and are currently engaged in providing services.

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* Meteorology has been defined by the Interdepartmental Committee for Meteorological Services as the science dealing in a general manner with the earth's atmosphere below the top of the stratosphere with a base including the air-sea interface, and particularly with observations of its current state, prediction of its motions, processes and future state, determination of its long-term manifestations and the application of the science to the activities of man.

Marine Meteorological Services consist of those facilities and activities established or operated to provide the specialized meteorological products needed by civil and military users operating in the marine environment of the oceans, estuaries, and inland waters. Included are all specialized observations, analyses and forecasts, communications, dissemination to users, and general agency support. Products of the Marine Meteorological Services are generally limited to tropospheric and such air-sea interface parameters as are necessary to describe sea surface conditions.

Department of Commerce: The ESSA-Weather Bureau has responsibility for forecasting the weather, issuing storm warnings, displaying weather and flood signals, and collecting and transmitting marine environmental information for the benefit of commerce and navigation. Additionally, the Safety of Life at Sea and the World Meteorological Organization (WMO) Conventions assign to the United States international responsibility for the provision of meteorological services to merchant shipping over large portions of the North Atlantic and North Pacific Oceans, as illustrated in figure 1.

Department of Transportation: The Commandant, United States Coast Guard has responsibility for promoting the safety of life and property on and over the high seas and waters over which the United States has jurisdiction, and for facilitating the preparation and dissemination by the Weather Bureau of weather reports, forecasts, and warnings essential to domestic and international commerce on and over such high seas and waters.

Department of Defense: The Chief of Naval Operations is responsible for procuring and disseminating to the naval service all necessary meteorological information. He has designated the Naval Weather Service Command to provide meteorological services for air, surface, and subsurface operations of the United States Navy and oceanographic forecasts for the Department of Defense.

FIGURE 1. AREAS OF U. S. SHIPPING FORECAST AND WARNING RESPONSIBILITIES UNDER THE WORLD METEOROLOGICAL ORGANIZATION

1. USER REQUIREMENTS

All users of the Marine Meteorological Service require warnings and forecasts of environmental conditions which affect the safety and efficiency of their individual activities. These activities vary in sensitivity to environmental conditions. The meteorological needs of the weekend sailor, the commercial fisherman, the transoceanic merchant mariner, and defense and security operations often are quite different. While there is a substantial common base in civil and military requirements, it is convenient to consider them separately since many of the military requirements demand highly specialized programs to produce information tailored to a specific military operation or weapons system. Therefore, adequate means which are not wholly dependent upon national or international civil programs must be provided in the Marine Meteorological Service programs to serve military purposes worldwide.

Civil

Civil requirements are tabulated in Table 1 to indicate the environmental parameters of operational significance to users, the amount of descriptive detail needed, and the time periods for which information is required. Because some users require extended forecasts of those environmental condictions which may be decisive in planning for future operations (e.g., icebreakers will or will not be needed), requirements have been further identified as "Operational" and "Planning".

The categories of marine user requirements in Table 1 are based on the following concepts:

HIGH SEAS - The open areas of the high seas.

These areas are generally traveled by large ships endangered only by severe environmental conditions. Though conditions of lesser severity adversely affect operational efficiency, the primary need of such vessels is for generalized environmental information covering broad geographical areas. Periodic updating of information is required and immediate advice concerning major changes is a matter of urgency.

OFFSHORE - Areas off the coast to a distance of approximately 250 miles, including the Great Lakes.

Medium sized ships, barges, and larger recreational craft which comprise the majority of vessels operating in these areas are more sensitive to environmental conditions than large vessels and can be endangered by weather and sea conditions of moderate intensity. Their operational efficiency can be adversely affected by environmental conditions of even lesser intensity. For these reasons and because offshore areas are frequently influenced by land-sea interactions resulting in rapid, localized environmental changes, the primary need is for relatively detailed environmental information covering small geographical areas. Frequent updating of forecasts and warnings is vital.

TABLE 1. CIVIL MARINE USER REQUIREMENTS

HIGH SEAS

PARAMETER	OPERATIONAL INFORMATION		PLANNING INFORMATION	
	Required Detail in Description	Forecast Period	Required Detail in Description	Forecast Period
Wind waves	Areas where waves $\geq$ 2 meters, 4 meters, etc.	0-48 hrs.	Areas with waves $\geq$ 2 meters and highest waves in area	3-6 days
Surface winds	Areas where speeds are $\geq$ 20 knots, 30 knots, etc. Directions to 8 points	0-48 hrs.	Areas where speeds $\geq$ 34 knots and highest speed in area	3-6 days
Fronts and pressure centers	Frontal positions. Location, movement, intensity, and change in intensity of centers	0-48 hrs.	Frontal positions. Location, movement, and general change in intensity of centers.	3-6 days
Pressure pattern	Isobars at 8 millibar intervals	0-48 hrs.		
Surface visibility	Areas in which visibility $\leq$ 1 mile	0-48 hrs.		
Significant weather	Precipitation areas; type and intensity. Sky cover.	0-48 hrs.		
Ice accretion	Areas of probable icing on superstructures or equipment	0-48 hrs.		
Air temperature	Temperature with resolution of 2°C	0-48 hrs.		
Sea surface temperature	Temperature with resolution of 2°C	0-48 hrs.		

OFFSHORE

Wind waves	Areas where waves $\geq$ 1 meter, 2 meters, etc.	0-48 hrs.	Areas where waves $\geq$ 1 meter and highest waves in area	3-6 days
Surface winds	Areas where speeds $\geq$ 15 knots, 20 knots, etc.	0-48 hrs.	Areas where speeds $\geq$ 30 knots and highest speed in area	3-6 days
Fronts and pressure centers	Frontal position and movement. Location, intensity and movement of pressure centers	0-48 hrs.	Location, movement and general change in intensity of centers	3-6 days
Ice	Location and character	0-48 hrs.	Areas which are impassable or require icebreakers	3-6 days
Surface visibility	Areas where visibility $\leq$ 5 miles	0-48 hrs.	Areas with visibility $\leq$ 1 mile	3rd day
Significant weather	Precipitation areas; type and intensity. Sky cover.	0-48 hrs.		
Ice accretion	Areas of probable icing on superstructures or equipment	0-48 hrs.		
Air temperature	Temperature with resolution of 2°C	0-48 hrs.		
Sea or water surface temperatures	Temperature with resolution of 2°C	0-48 hrs.		

TABLE 1 (Continued)

COASTAL, INLAND LAKES AND WATERWAYS

PARAMETER	OPERATIONAL INFORMATION		PLANNING INFORMATION	
	Required Detail in Description	Forecast Period	Required Detail in Description	Forecast Period
Wind waves	Waves ≥ 1 foot, 2 feet, etc.	0-48 hrs.	Areas with waves ≥ 2 feet and highest waves	3-6 days
Surface winds	Directions and speeds	0-48 hrs.	Areas with speeds ≥ 20 knots and highest speeds	3-6 days
Surface visibilities	All values	0-48 hrs.	Areas with visibility ≤ 1 mile	3rd day
Significant weather	Precipitation areas; type and intensity. Sky cover. Probability of thunderstorms.	0-48 hrs.	Probability of precipitation. Cloudiness.	3rd day
Air temperature	Temperature with resolution of 2°C	0-48 hrs.	Temperature with resolution of 2°C	3rd day
Water temperature	Temperature with resolution of 2°C	0-48 hrs.		
Humidity	Humidity with resolution of 10%	0-48 hrs.		
Breakers and surf	Height and character	0-36 hrs.		
Ice accretion	Areas of probable icing on exposed equipment	0-48 hrs.		
Storm surge	Height in feet	0-48 hrs.		

COMMERCIAL FISHING (OFFSHORE AND HIGH SEAS FISHING AREAS)

Wind waves	Areas where waves ≥ 1 meter, 2 meters, etc.	0-48 hrs.	Areas with waves ≥ 1 meter and highest waves in area	3-6 days
Surface winds	Areas where speeds are ≥ 15 knots, 20 knots, etc. Directions to 16 points.	0-48 hrs.	Areas with speeds ≥ 30 knots and highest speed in area	3-6 days
Fronts and pressure centers	Frontal positions and movement. Location, movement, intensity of centers	0-48 hrs.	Location, movement, intensity of centers	3-6 days
Ice	Location and character	0-48 hrs.	Areas which are impassable	3-6 days
Surface visibility	Actual or predicted values when ≤ 5 miles	0-48 hrs.		
Significant weather	Precipitation areas; type and intensity. Sky cover.	0-48 hrs.		
Ice accretion	Areas of probable superstructure icing.	0-48 hrs.		
Air temperature	Temperature with resolution of 2°C	0-48 hrs.		
Sea surface temperature	Temperature with resolution of 2°C	0-48 hrs.		

In addition to the tabulated requirements all marine users require specific warnings of hurricanes, severe storms, and other weather or wave conditions that present special hazards.

COASTAL, INLAND LAKES AND WATERWAYS - The coastal areas in the oceans and Great Lakes to a distance of about 15 miles from shore, and inland lakes and rivers.

Most marine recreational activities, including small boating and swimming, as well as commercial harbor and anchorage activities, take place in these areas. These activities are extremely sensitive to environmental conditions with life and property often imperiled by rapidly developing localized disturbances. The primary need within these areas is for detailed local environmental information carefully monitored and rapidly updated.

COMMERCIAL FISHING -

Requirements of the commercial fishing industry have been treated separately from the geographical categories for the following reasons:

Meteorological requirements of commercial fishermen operating on the high seas and those operating in offshore areas are nearly identical.

United States commercial fishing often takes place in geographical areas remote from those in which other user groups operate.

Commercial fishing requirements for specialized physical oceanographic support are not included in this plan. Plans for this support are a part of the Federal Plan for Marine Physical Environmental Prediction.

Military

Military/naval operations require observations and detailed forecasts of environmental conditions over the oceans and adjacent land masses. Meteorological information required by forces operating on the high seas usually differ considerably from that required when operating offshore and the needs of a carrier task force differ from that of Polaris submarines. This diversity of military operations and the need for tailored environmental information make it difficult to divide specific military requirements for marine meteorological services into geographic categories similar to those for civil users. It seems more useful to indicate the magnitude and diversity of these requirements by considering the effects of meteorological and air-sea interface parameters on various types of military operations and to list the general types of meteorological services and information required. This information is contained in Table 2.

TABLE 2. EFFECTS OF METEOROLOGICAL AND AIR-SEA INTERFACE PARAMETERS ON MILITARY OPERATIONS

	SURFACE OPERATIONS						AIR OPERATIONS					
PARAMETERS	Seamanship and Navigation	Anti-Submarine	Amphibious	Anti-Air	Atomic/Biological Chemical	Polar	Airmanship and Navigation	Launch and Recovery	Weapons Delivery	Tactical Support	Surveillance	Air Defense
Wind vs Height		1		3	3		2	3	3	2	2	2
Temperature vs Height					2	1	2	1	1			
Clouds	2	1	1	2	3	1	2	3	3	3	3	2
Precipitation	2	2	2	2	3	2	2	2	1	3	3	2
Severe Weather	3	3	3	3		3	3	3	3	3	3	3
Density vs Height				2			2	2	1	3	1	2
Air Frame Icing							3	2	3	3	3	3
Refractive Index	1	2	2	2		2	2	1	2	2	3	3
Clear Air Turbulence				3	3		3	1	2	2	2	2
Contrails				2					2	2	2	2
Flight Level Visibility							2	3	3	3	2	2
Shock Wave (Sonic)							2		1	1	1	
Surface Air Temperature	2	1	2	2	1	3	1	3	1	2	1	
Sea Surface Temperature	1	2	2	1	1	3	1	1		2	1	
Surface Wind	3	3	3	3	3	3		3	3	3	3	
Surface Visibility	3	3	3	2	1	3	2	3	2	3	3	
State of the Sea	3	3	3	3	2	3	1	3		3	2	
Sea Ice	1	1	1	2	1	3		1	1	1	1	
Surface Air Density								2		3	2	
Structural Ice	2	2	1	1		3		3	3			
Surf	1		3									

2. SERVICE CONCEPTS

As noted earlier, there are significant differences between civil and military marine meteorological requirements. These differences result in somewhat different concepts for service programs to meet the requirements.

Department of Commerce

The ESSA-Weather Bureau concepts for service programs to meet civil requirements are:

- Warnings, as well as forecasts and other information of general utility to broad segments of users, will be provided by ESSA-Weather Bureau.

- The more individualized and tailored products for individual commercial concerns, other than those products that have to do with safety of life and property, may be provided by private meteorologists from basic information available from ESSA-Weather Bureau.

Department of Defense

The Navy concept for service programs to meet military requirements is to provide a broad spectrum of general operational products as well as products tailored to meet individual military operational requirements.

Department of Transportation

The Coast Guard generally looks to the ESSA-Weather Bureau for marine meteorological services and will assist in disseminating forecasts and warnings to marine users. Specialized analyses and forecasts for rescue coordination and control will be provided by Coast Guard facilities and when the Coast Guard is participating in operations with the Navy it will be supported by Department of Defense meteorological service organizations.

Federal Programs

The Federal programs developed from these general concepts are based on the following relationships between the Marine, Basic and Specialized Meteorological Services and between civil and military programs:

a. The civil and military programs for the Marine Meteorological Service contribute to and derive maximum benefit from ESSA's Basic Meteorological Service for:

   - Observations at the earth's surface, in the upper atmosphere, and from weather satellites over the oceans and land masses.

- Basic analyses and forecasts.

- Warnings of tropical cyclones and severe local storms.

- Communications support for collection and movement of meteorological information between weather service offices, and in some cases, distribution of products to users.

b. The costs for Basic Meteorological Service are not reflected in this plan. Improvements necessary to support the Marine and the other specialized meteorological services are planned and budgeted as part of the Basic program.

c. Some marine meteorological service requirements are common to both civil and military users. As planned services to civil users are implemented, many of these common requirements can be met by ESSA-Weather Bureau products. This will free some military resources to concentrate on requirements unique to military operations.

d. Until services to civil users have been expanded, products designed for military users which are appropriate and can be made available will be used to meet requirements of the civil users. This use of military products will be "ad interim" except in those cases where common requirements can be met most effectively and economically by their continued use.

The objectives of the civil and military programs in the Marine Meteorological Service are:

Commerce

It is the objective of the Department of Commerce to provide timely warnings and forecasts of meteorological and air-sea interface* conditions for the high seas of the North Atlantic and North Pacific Oceans and for coastal and inland waters of the United States.

To meet this objective, the broad-scale analysis and forecasting programs at the Weather Bureau's National Meteorological Center (NMC) will be expanded, Marine Forecast Centers (MFC) will be established, and selected weather service offices will be strengthened. NMC will produce basic meteorological guidance and the high seas graphic analyses and forecasts. The MFC's, using this basic guidance and the high seas products produced at NMC, will support designated areas of the high seas and offshore users as shown in Figure 2 by producing alphanumeric products and by maintaining a continuous marine weather watch to insure rapid issuance of warnings. Selected weather service offices will provide support to coastal, inland lakes and waterways, and commercial fishing users. Table 3 lists planned responsibilities for commercial fishing areas. The Marine Meteorological Service will continue to rely upon the Basic Meteorological Service for observational support.

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* Discussed in detail in the Federal Plan for Marine Physical Environmental Prediction, April 1, 1968.

FIGURE 2. PLANNED MARINE FORECAST CENTERS (MFC)
Area Coverage of Offshore Products Shown By Hatching.
Miami, Honolulu, San Francisco and Washington have High Seas Responsibilities as well

TABLE 3. PLANNED RESPONSIBILITIES FOR COMMERCIAL FISHING AREAS

Responsible ESSA-Weather Bureau Office	Fishing Area
Boston	Northern Georges Bank and Grand Banks
Washington	Southern Georges Bank to Florida
Miami	Gulf of Mexico and Western Caribbean shrimp areas
San Juan	Caribbean shrimp area
Los Angeles	Central and Southern California fishing areas
Seattle	Canadian-U.S. salmon area
Anchorage	Alaskan and Aleutian salmon areas
Honolulu	Hawaiian tuna area
San Francisco	Eastern North Pacific fishing area
Guam	Trust territories

Internal communication support for the Marine Meteorological Service will be provided by the Basic Meteorological Service systems for collecting observations and exchanging and coordinating analyses, forecasts and warnings. Information from overseas areas will be obtained from teletypewriter and high-speed communication systems; domestic information will be obtained from basic teletypewriter networks. Analyses, forecasts and warnings will be distributed from NMC, Hurricane Centers, and the National Severe Local Storms Forecast Center over these teletypewriter networks and Department of Commerce facsimile systems.

To insure reliable distribution of marine meteorological service products to users, existing marine radio broadcasts will be continued and additional broadcasts -- compatible with the varying reception capabilities of users - will be established. High seas products will be disseminated through multichannel commercial marine broadcast facilities (paid transmissions). Offshore and commercial fishing products will be disseminated through commercial broadcast facilities (as a public service whenever possible) and by Coast Guard stations. Coastal and inland lakes and waterways products will be disseminated by means of the ESSA Weather Wire teletypewriter system to the press, radio, and television, as well as by Coast Guard marine broadcasts, Commerce-operated broadcasts, and automatic telephone answering systems.

Transportation

The Coast Guard will continue to cooperate with the Department of Commerce by assisting in the dissemination of forecasts and warnings to marine users. The services involved are:

- Marine weather broadcasts by Coast Guard radio stations to supplement Commerce VHF/FM broadcasts and complement commercial radio station coverage.

- Participation by Coast Guard stations in the Coastal Warning Display System.

Defense

Marine Meteorological Service in the Department of Defense (DOD) involves the acquisition, collection, analysis and processing of all available environmental data. Included are those data obtainable from the Basic Meteorological Service. Supplementary data sources are maintained by the DOD as required to satisfy critical operational needs. On the dissemination side, customized analysis and forecast products are made available to the broad spectrum of users with varied numbers/types of requirements.

Resources of the Naval Communications Command worldwide are used for the broadcast dissemination of environmental warnings, forecasts and advisories directed to the non-specialized user. Products are originated by designated elements of the Naval Weather Service Command and consist of radiotelegraph, radioteletype and radiofacsimile transmissions. The six primary shore points of origin for these services are the Fleet Weather Centrals located at Guam; Pearl Harbor; Alameda; Norfolk; and Rota, Spain, and the Fleet Weather Facility at Suitland.

Specialized environmental products are similarly disseminated with additional emphasis on unique user requirements. Most tailored products are provided by addressed message when dissemination by broadcast is inappropriate.

The centralized data collection, processing and forecasting point within the Naval Weather Service Command is the Fleet Numerical Weather Central (FNWC) Monterey. The "hubbing" point for the Naval Environmental Data Network, FNWC Monterey, transmits worldwide initially processed gridded data via high speed data link to the aforementioned computerized Fleet Weather Centrals/Facilities. The primary source of foreign observational data is the high speed automated data network operated by the United States Air Force and utilized by the Naval Weather Service Command because of long-haul timeliness advantages.

3. EXISTING SERVICES

Observations

Meteorological observations to meet the needs of the general public and the common needs of specialized meteorological services for various user groups are, as previously noted, a responsibility of the Basic Meteorological Service. There are no civil programs for meteorological observations solely for the Marine Meteorological Service; all observational data are obtained from Basic sources and from observing programs of the Department of Defense. The Basic Meteorological Service provides the following observations:

- Surface observations from land and oceanic areas to support broad-scale analyses and forecasts.
- Surface observations from the Cooperative Merchant Ship Observing Program to supplement data coverage over the oceans.
- Surface observations from the Cooperative Coastal Observing Network to support detailed forecasts for coastal and offshore areas.
- Tidal data from coastal stations to support storm surge predictions.
- Upper-air observations from land and ocean stations as fundamental inputs to analysis and prediction by computers.
- Weather radar observations of thunderstorms and precipitation over the United States and observations of tropical cyclones and dangerous storms in the offshore areas.
- Weather satellite observations of the earth's cloud patterns on a daily basis for locating and estimating the intensity of storms and tropical cyclones, especially in the less frequently traveled portions of the oceans.
- Weather reconnaissance observations of the detailed characteristics and location of tropical cyclones and major storms over the oceans to support accurate, timely warnings to marine users.

Marine meteorological services for military users, like those for civil users, depend upon the Basic Meteorological Service for observational support. The worldwide scope and frequently more demanding needs of military users require more observational data than are provided by the basic programs. To meet this need for supplemental data, the Navy has established a marine observation program.

All commissioned naval vessels are required to record and report weather observations when underway and, under certain conditions, while in port. Surface observations are made at 6-hourly intervals as an additional duty by nonmeteorological personnel aboard most of the ships. To fulfill requirements for more accurate and detailed observations, as well as to perform other essential functions, meteorological personnel have been assigned and more sophisticated meteorological equipment provided to approximately 70 ships. All of these make scheduled surface observations for synoptic and aviation purposes; approximately 50 are equipped to make upper-air observations. The Navy also obtains data from Navy Oceanographic/Meteorological Automatic Devices (NOMADs). These unmanned buoys, currently undergoing "Research and Exploratory Development", are instrumented to observe and transmit environmental data from oceanic areas. Although the Navy's marine observational program is conducted to fulfill military requirements, observations are made available to other agencies.

Analyses and Forecasts

There are three types of analysis and forecast centers involved in the Marine Meteorological Service. They are primary, area and specialized centers. Each of these centers and its products are discussed in subsequent paragraphs.

The Department of Commerce operates four primary centers which provide products and support to the Marine Meteorological Service in addition to their much larger roles in the Basic Meteorological Service. The National Meteorological Center (NMC) at Suitland, Maryland provides broad-scale analyses and forecasts on a hemispheric basis, plus graphic products for facsimile transmission to high seas users. The National Environmental Satellite Center, also at Suitland, operates the National Operational Meteorological Satellite (NOMS) System to provide global cloud cover mosaics and interpretive data on a daily basis. The NOMS System also provides direct local readouts of cloud cover pictures from weather satellites to suitably equipped shore stations and ships. The National Hurricane Center at Miami, Florida provides warnings of tropical cyclones (hurricanes) in the North Atlantic Ocean (West of 35°W), the Caribbean Sea and the Gulf of Mexico. Forecast centers in San Francisco and Honolulu provide these services in the Eastern and Central Pacific east of 180°. Warnings of severe local storms (thunderstorms and associated winds, hail and tornadoes) over the 48 conterminous states and coastal waters are provided by the National Severe Storms Forecast Center in Kansas City, Missouri.

Twenty-five area forecast centers are operated by the Department of Commerce in the 50 states and Puerto Rico. They provide analyses, forecasts and warnings on a regional basis -- including coastal areas. Many of these centers contribute to marine meteorological services. The centers at Boston, Washington, Miami, New Orleans and San Juan provide limited forecast and warning services for fishing fleets operating in the North Atlantic Ocean (West of 60°W), the Caribbean Sea, and the Gulf of Mexico. Forecasts and warnings for the Great Lakes are issued by the center at Chicago.

Three area centers also provide analysis and forecast services to meet United States' responsibilities under the World Meteorological Organization. The center at Washington issues high seas forecasts and warnings for the North Atlantic (West of 35°W). Similar services are provided by the centers at San Francisco and Honolulu for the eastern and central North Pacific Ocean. High seas service responsibilities in the western North Pacific Ocean (between 135°E and 160°E) are met by the Department of Defense (See figure 1).

The National Weather Records Center is operated by the Department of Commerce at Asheville, N. C. as part of the ESSA-Environmental Data Service. This specialized center is responsible for processing and archiving meteorological records, including reports from naval and merchant vessels. It is also responsible for recording and describing the climate of the oceans in support of national requirements.

Ship weather logs are received at the National Weather Records Center from about 2100 merchant vessels each year. Observations entered in these logs are checked, recorded, summarized, and archived. Summaries are included in various Commerce, Coast Guard, Navy, and World Meteorological Organization publications. In addition, as part of a World Meteorological Organization program, data cards are exchanged with other major maritime nations. The Navy provides budgetary support to these programs.

Since the primary, area, and specialized centers support the Basic Meteorological Service, the Marine Meteorological Service and other specialized user groups as well, their funding is prorated according to the effort required for each type of support. The Marine Meteorological Service budgets reflect the costs of preparing the specialized products for marine users.

The Department of Transportation (Coast Guard) operates two weather offices which function as specialized centers in support of Search and Rescue (SAR) operations at sea. These offices, located at the Maritime Search and Rescue Control Centers in New York and San Francisco, provide advice to commanders directing rescue operations and prepare specialized forecasts for transmission to vessels, aircraft, and coordination centers engaged in SAR operations.

The Navy operates primary, area and specialized centers to provide service to military users. Its Fleet Numerical Weather Central at Monterey, California functions as a primary center to prepare global analyses and prognoses for use by the elements of the Naval Weather Service Command. These products also go to Operational Control Centers.

Fleet Weather Centrals/Facilities located at Pearl Harbor, Hawaii; Guam; Suitland, Maryland; Norfolk, Va.; and Rota, Spain, operate as area centers. They use the broad-scale products from the Fleet Numerical Weather Central and, where available and applicable, products from the National Meteorological Center to prepare detailed analyses, forecasts and warnings for their areas of responsibility (see Figure 3). Fleet Weather Central products are disseminated to naval operating forces and to smaller naval environmental units by the Naval Communications System.

In addition to the above listed area centers, the Navy operates Fleet Weather Centrals or Facilities at Yokosuka, Japan; Sangley Point, Republic of the Philippines; Alameda, Calif.; San Diego, Calif.; Jacksonville, Fla.; Quonset Point, R.I.; Kodiak, Alaska; Keflavik, Iceland; London, England; and Pensacola, Fla. as specialized centers. These centers provide environmental services, including forecasts and warnings, tailored to specific naval operating and training areas. Many Naval meteorological units also have functional responsibilities; e.g., Fleet Weather Facility, Kodiak and Naval Weather Service Environmental Detachment, Argentia, Newfoundland provide specialized ice forecasting services; Fleet Weather Centrals at Alameda, Norfolk and Guam operate the Navy's Optimum Track Ship Routing (OTSR) program. OTSR offers a high probability of one or a combination of the following: 1) Least steaming time enroute; 2) The best weather route; and 3) By-passing areas where storm damage may be expected. This service is available to Naval ships, MSTS ships and vessels under contract to the government. A significant activity of the Naval Weather Service Command is to participate in and provide support to units engaged in antisubmarine warfare (ASW).

Specialized processing of meteorological observations from naval units and the preparation of marine climatological studies for naval use are performed under contract by the National Weather Records Center, Asheville, N. C.

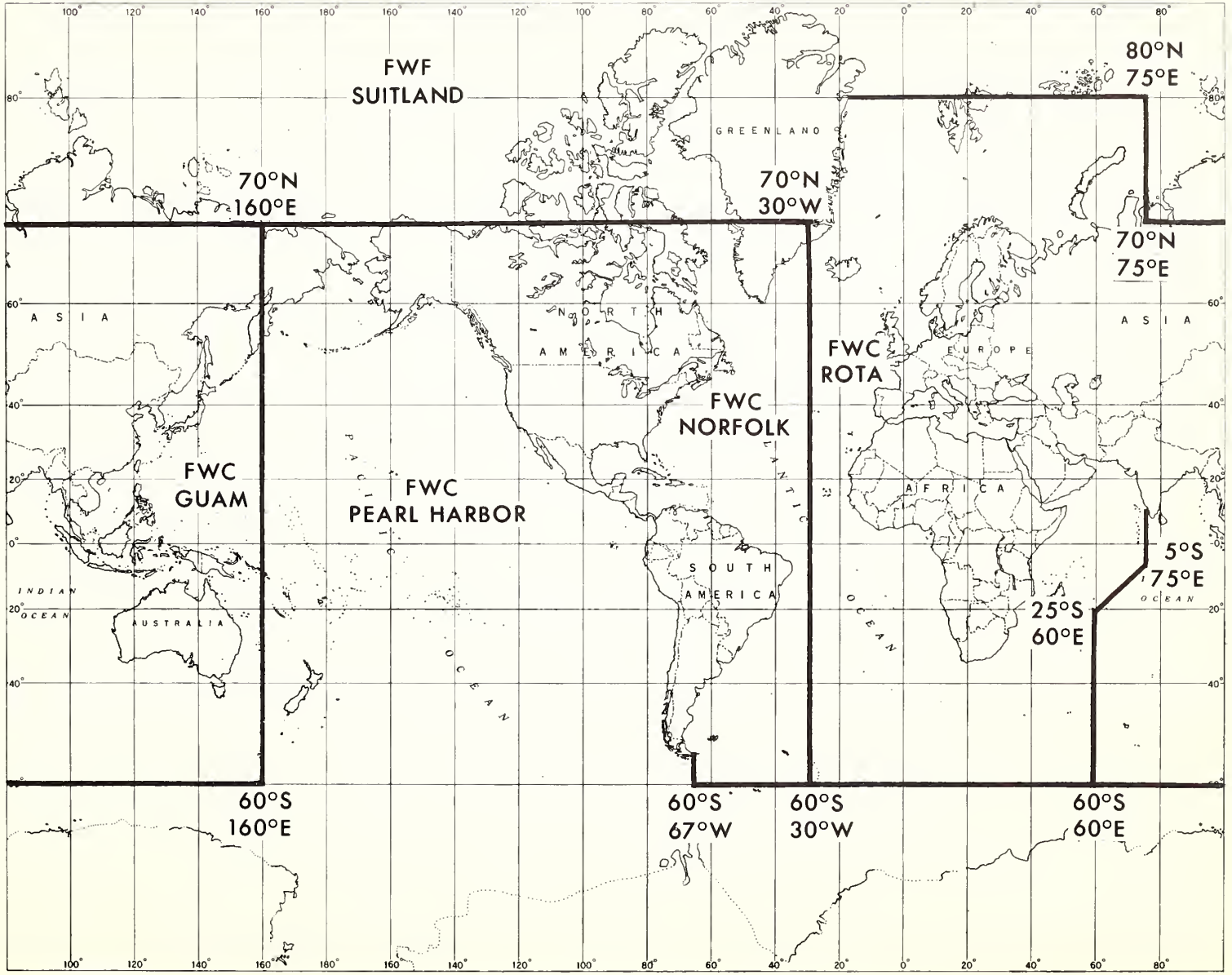
Communications

Just as the Marine Meteorological Service relies upon the Basic Meteorological Service for observational data and broadscale analyses and forecasts, there is similar dependence upon Basic weather communications systems for support. In particular, the Marine Meteorological Service relies on these Basic systems:

- Teletypewriter systems (Services C and O) operated by the Federal Aviation Administration for ESSA-Weather Bureau.
- Radar Reporting and Warning Coordination System - a teletypewriter system operated by the Department of Commerce.
- Teletypewriter and high speed circuits operated by the Department of Commerce for collecting and exchanging overseas information.

FIGURE 3.

NAVAL WEATHER SERVICE COMMAND AREAS OF RESPONSIBILITY



- ESSA's Weather Wire - a teletypewriter system to distribute forecasts and warnings to the press, radio and television. Figure 4 shows the areas covered by this system.

- Facsimile networks operated by Department of Commerce.

- Continuous VHF/FM radio broadcasts* operated by the Department of Commerce.

Although, these communications systems supply a large measure of the communications support for the Marine Meteorological Service, they must be supplemented by specialized civil and military programs. There is increasing reliance upon available high speed civil and military computer-to-computer data collection and exchange facilities. This includes the Naval Environmental Data Network and the Air Force Automated Weather Network. Department of Commerce links such as those between Washington and Montreal, Canada; Offenbach, Germany; Tokyo, Japan; and Melbourne, Australia (the latter two links are in final planning stages as part of the World Weather Watch Telecommunications program) contribute to marine meteorological services.

The Department of Commerce operates automatic telephone answering systems and has arranged for radio broadcasts to marine users over Coast Guard, Navy, Army and commercial radio facilities.

Automatic telephone answering systems operate throughout the year at Baltimore, Washington, Juneau, Seattle, Chicago and Los Angeles; service is also provided at Boston and Providence during the boating season. These systems provide the latest forecasts and warnings for marine users in their areas. Similar information may be obtained from other coastal offices of the Weather Bureau through listed telephones.

More than 2,000 commercial radio and television stations broadcast marine weather forecasts and warnings several times daily as a public service of considerable benefit to small-boat operators with no cost to the Federal government. Forecasts and warnings for coastal and offshore areas are also transmitted by 31 Coast Guard, 10 Army (in Alaska), and 39 commercial radiotelephone and radiotelegraph facilities. These stations, though generally lowpowered, serve a broad spectrum of the maritime community. High seas analyses, forecasts, and warnings are provided to merchant ships operating in the western North Atlantic and eastern and central North Pacific Oceans by Navy and commercial radiotelegraph broadcasts. Warnings for the western North Atlantic and eastern North Pacific are transmitted by commercial high seas radiotelephone stations. Analyses and forecasts are also available from Navy facsimile transmissions to suitably equipped merchant ships.

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* These broadcasts on 162.55 MHz have a range of about 40 miles; 19 facilities at coastal or inland water locations are now in operation. Figure 5 shows the existing and planned locations of these radio stations. Detailed information on their location and broadcast contents may be obtained from local Weather Bureau offices or from the Director, Weather Bureau.

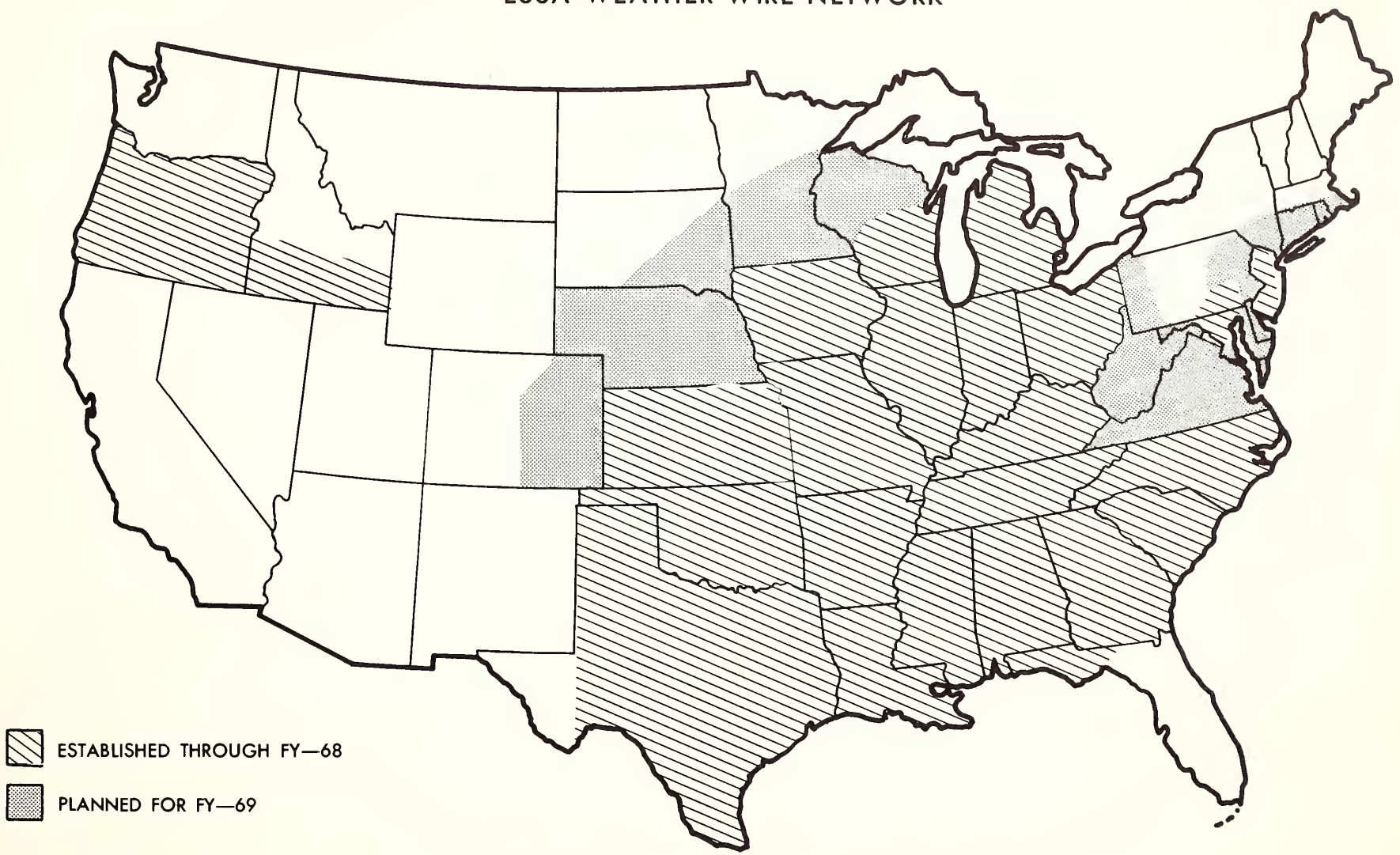
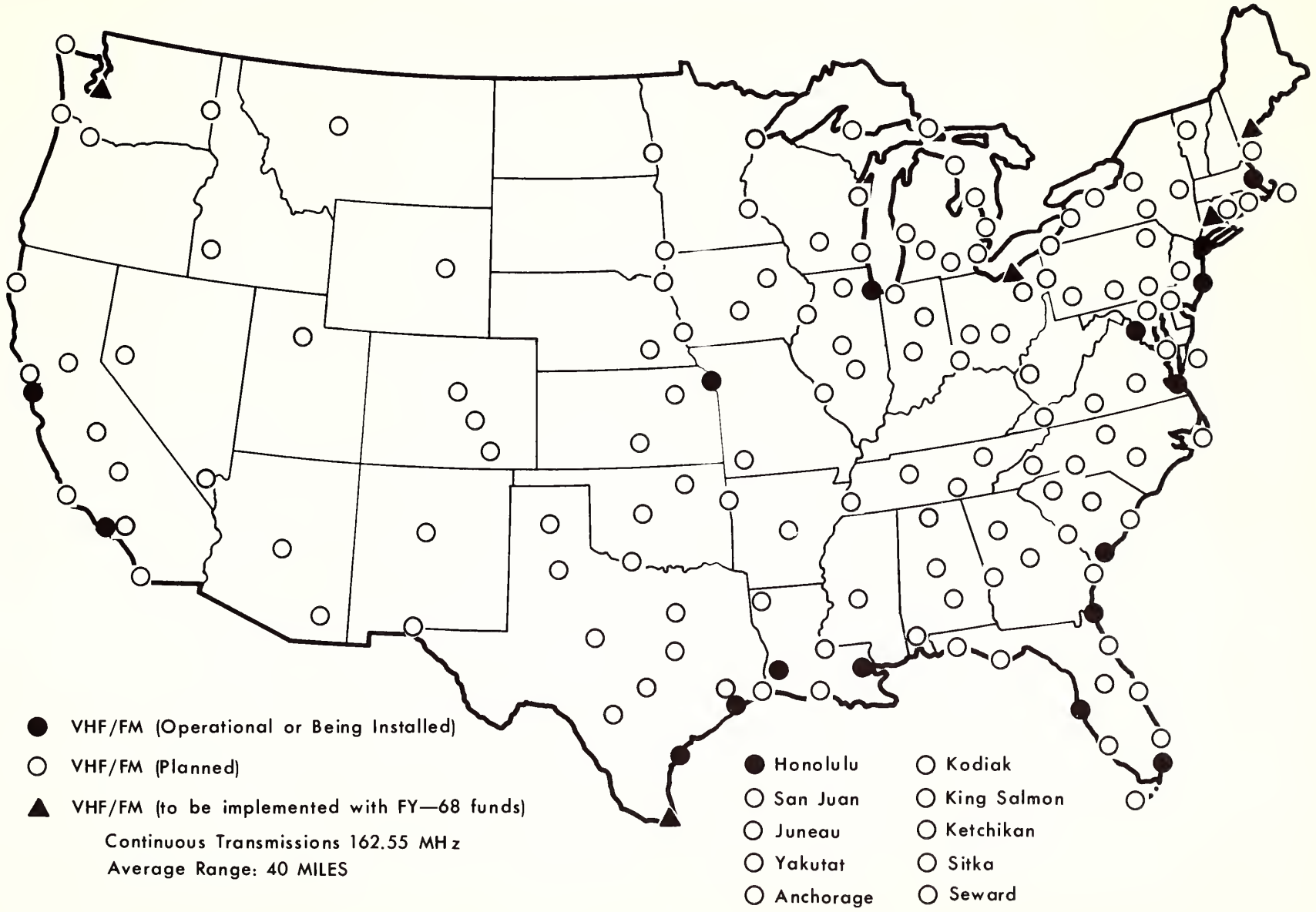


FIGURE 4. ESSA WEATHER WIRE

FIGURE 5. DEPARTMENT OF COMMERCE VHF/FM BROADCASTS



Communications support is provided at no cost to the Department of Commerce by the Coast Guard, Army, Navy, and many commercial facilities.

To promote maritime safety, the Department of Transportation (Coast Guard) cooperates with the Department of Commerce (Weather Bureau) by providing broadcasts of coastal marine weather information to shipping and other maritime users at 31 locations. These broadcasts were established to fill gaps in commercial radio station coverage, and, though carried out on a not-to-interfere basis, constitute a major effort by the facilities concerned. Broadcasts -- usually plain language voice transmissions -- are scheduled at 6 or 12 hourly intervals; with warnings of hazardous conditions transmitted upon receipt and repeated periodically. The texts for these broadcasts are prepared by the Weather Bureau and delivered to the nearest Coast Guard communications office.

The Naval Communications System provides support to military programs. Meteorological traffic is handled in the same manner as other traffic, and there are no centers or units dedicated exclusively to meteorological communications. However, equipment needed to transmit and receive meteorological data is installed directly in the weather offices. Additionally, the Naval Environmental Data Network provides for the dissemination of meteorological and oceanographic computer products from the Fleet Numerical Weather Central at Monterey to specially equipped locations in the United States and overseas.

Meteorological information is transmitted to operating Naval forces by means of Navy radio (continuous wave, teletypewriter, facsimile and voice) broadcasts. These broadcasts are prepared by the Fleet Weather Centrals and Facilities and include observations, analyses, forecasts, and warnings. In preparing broadcasts, the centrals and facilities make use not only of their own specialized products and those of Fleet Numerical Weather Central at Monterey, but also -- insofar as possible -- products of the Basic Meteorological Service and other data as received from the Federal Aviation Administration's weather teletypewriter networks, the Department of Commerce's National and High Altitude Facsimile Networks, and the Air Force's Automated Weather Network and teletypewriter systems.

Dissemination to Users

This function includes the preparation of local marine forecasts, advisories, and warnings; the operation of offices engaged in the preparation of these products; the provision of briefing services; and the operation of visual display systems. It should be noted, however, that the principal means for disseminating marine products to civil users are by commercial communications media (radio and television), government communications channels (voice and radiotelegraph broadcasts), and automatic telephone answering systems.

Currently, 14 Department of Commerce Area Centers issue forecasts and warnings for nearby coastal and offshore waters (to 50 miles seaward). In addition, two Area Centers and 12 weather offices provide similar services for inland lakes, dams and reservoirs. Personal briefing service is available at all of these activities; however, the majority of civil marine users rely on the communications systems, discussed earlier, for information and advice.

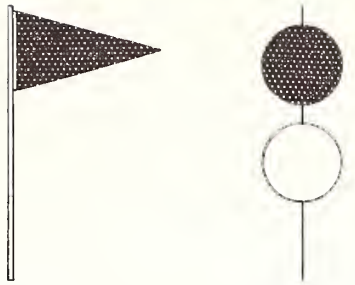
The Coastal Warning Display System is a cooperative network of visual (flag and light) displays maintained at prominent locations along the seacoasts, the Great Lakes, and inland waterways to advise boating and other marine interests when small craft, gale, storm and hurricane warnings, issued by the Weather Bureau, are in effect. Yacht clubs, marinas, and other private marine activities; state and local governments; as well as the Coast Guard and Weather Bureau participate in this network of more than 550 display stations. The Department of Transportation (Coast Guard) has 163 lighthouses, lifeboat stations, lightships, and other facilities participating in the Coastal Warning Display System. The Department of Commerce operates 75 displays; the remainder are operated on a cooperative basis by non-Federal interests. In addition, small craft warnings are displayed by state police patrol craft in Chesapeake Bay and in the New York City area. Figure 6 shows the light and flag displays for various warnings.

The focal point of the environmental support generated by the Naval Weather Service Command is at the operating level. The primary purpose is to support operational decisions by providing meteorological support and advice. The Navy operates small weather service offices at all major naval commands and aboard many larger ships. These offices utilize the products of the Naval Weather Service Command, as well as those available from the Basic Meteorological Service and other sources. They interpret these products for local use, prepare local area and route forecasts, and provide weather briefing services. Briefings generally are conducted in person but may also be provided by telephone or closed circuit television. More than 100 weather service offices, as well as the larger area and specialized centers, provide these services in support of the military Marine Meteorological Service programs.

General Agency Support

General agency support functions cover the activities which agencies must carry on to operate efficient meteorological service programs and provide effective, reliable support to their users. It includes training, maintenance, internal support and management above the operating level.

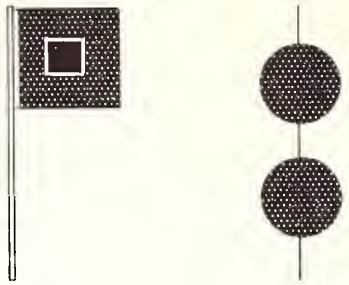
SMALL CRAFT



DAYTIME SIGNAL NIGHT SIGNAL

One RED pennant displayed by day and a RED light over a WHITE light at night to indicate winds as high as 33 knots (38 m.p.h.) and/or sea conditions considered dangerous to small craft operations are forecast for the area, (see note on last page).

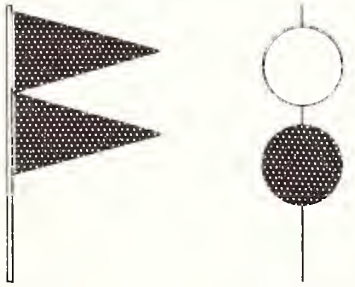
STORM



DAYTIME SIGNAL NIGHT SIGNAL

A single square RED flag with a BLACK center displayed during daytime and two RED lights at night to indicate that winds 48 knots (55 m.p.h.) and above are forecast for the area. If the winds are associated with a tropical cyclone (hurricane), the "Storm Warning" display indicates winds 48 to 63 knots (55 to 73 m.p.h.) are forecast.

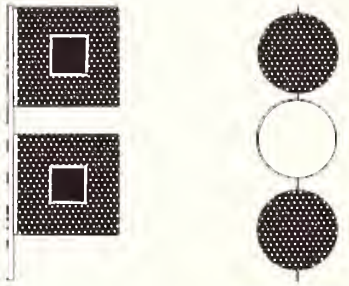
GALE



DAYTIME SIGNAL NIGHT SIGNAL

Two RED pennants displayed by day and a WHITE light above a RED light at night to indicate winds within the range 34 to 47 knots (39 to 54 m.p.h.) are forecast for the area.

HURRICANE



DAYTIME SIGNAL NIGHT SIGNAL

Displayed only in connection with a tropical cyclone (hurricane). Two square RED flags with BLACK centers displayed by day and a WHITE light between two RED lights at night to indicate that winds 64 knots (74 m.p.h.) and above are forecast for the area.

FIGURE 6. EXPLANATION OF LIGHT AND FLAG DISPLAYS

Training

Accurate sea, swell, surf, storm surge, and other marine forecasts require adequate training in physical oceanography, as well as in meteorology. While forecasters currently supporting civil marine users are qualified meteorologists, only a few have received formal oceanographic training. Selected Department of Commerce meteorologists are now receiving this training in university programs.

Coast Guard personnel receive training at Navy schools to support Coast Guard participation in the Basic Meteorological Service observational program and meet Coast Guard requirements as well. No meteorological training is conducted specifically to support the Marine Meteorological Service.

As part of its Naval Technical Training Center, the Navy operates three meteorological technician training schools for enlisted personnel at Lakehurst, N. J., to provide specialized technical training in meteorology and oceanography tailored primarily to the needs of the Navy and Marine Corps. Small numbers of personnel from the Coast Guard and other services are accommodated.

The Aerographer's Mate Class "A" School provides meteorological training at the basic level and the "B" School provides training at a more advanced level for selected Aerographer's Mates. The Aerographer's Mate Class "C" School provides the following training:

Upper-air observing	6 weeks,
APT*	3 weeks,
Air-Ocean	7 weeks.

The Naval Postgraduate School at Monterey, California has an environmental sciences program to qualify commissioned officers as meteorologists with a working knowledge of oceanography as applied to naval operations. Through advanced study, they may also conduct independent research. Bachelor or Master of Sciences degrees in meteorology as well as oceanography are awarded to qualified graduates. Officers from other United States Services as well as foreign countries also attend. A limited number of naval officers are selected for doctoral studies at civilian universities.

All Navy-conducted meteorological training is directed toward fulfilling its overall military requirements. No training is specifically directed to the Marine or other specialized meteorological services.

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* Automatic Picture Transmissions from meteorological satellites.

Maintenance

This function includes all measures taken to keep meteorological equipment in proper operating condition and to repair this equipment when it fails.

Department of Commerce maintenance programs are operated and funded as a part of the Basic Meteorological Service. The Department of Transportation similarly has no maintenance programs specifically for marine meteorological services.

Maintenance of meteorological equipment in the Navy is a command responsibility and is generally provided at the local level. However, the Navy also maintains two central and eight area overhaul facilities to repair or overhaul more complex meteorological instruments. A meteorological and oceanographic equipment program has also been established which, by utilizing meteorological officers with electronics training and civilian electronic engineers working as teams, provides special assistance to fleet and shore-based commands.

Internal Support

General mission-related activities in support of meteorological operations within an agency are necessary parts of providing service to users. These activities include the following types of programs:

- Engineering support for planning, preparing specifications, surveying equipment sites for suitability, inspecting and calibrating new equipment.

- Scientific studies and consultant services to determine the feasibility of new programs and to increase the effectiveness of on-going programs.

- Quality control of products to assure that accuracy and productivity standards are maintained.

- Employee housing and housekeeping or utility-type equipment at remote area locations.

Internal support activities within the Department of Commerce are consolidated for the most part under the Basic Meteorological Service. They are provided by ESSA, Weather Bureau, and Regional Headquarters staffs when necessary for specialized marine user programs.

Internal support activities within the Navy include technical support provided by the Naval Weather Service Command and the Naval Air Systems Command; engineering support provided by Naval Industrial Management Offices and Public Works Offices; and management, supervision, administration, and logistical support provided at the local operating level.

Management Above Operating Level

This activity includes all executive management, supervision, administration, planning and logistical support provided from above the operating unit level to support the Marine Meteorological Service. It is carried on within the Department of Commerce by full or part-time marine specialists on the ESSA, Weather Bureau and Regional Headquarters staffs. Management above the operating level within the Navy is provided by a part of the staff effort at the Naval Weather Service Command and Naval Air Systems Command.

4. AREAS OF POTENTIAL IMPROVEMENT

User requirements have been reviewed and current Marine Meteorological Services listed. Potential improvements derived by comparing the requirements with the current services may be placed in three categories: Product improvements, support improvements and improvements requiring supporting research and development.

Product Improvements

Current products fall short of fulfilling all civil user requirements. Forecasts and warnings do not include all parameters of operational significance to users and are not updated with sufficient frequency; facsimile charts on marine broadcasts are not designed for use by nonmeteorologists; and many users cannot receive weather information due to lack of adequate dissemination capability. The requirements of military marine users are being adequately met for the most part by existing programs; however, there are some areas that need improvement.

Support Improvements

Support improvements have been identified in three subcategories:

- Common - those which are common to civil and military programs.
- Civil - those which are unique to civil programs.
- Military - those which are unique to military programs.

Common

- Surface and upper-air observations from remote oceanic areas are inadequate to support accurate forecasts and warnings. This is particularly true for areas off normal shipping lanes.
- Surface observations from United States coastal and offshore areas are inadequate to support the detailed analyses, forecasts and warnings required in these areas frequented by smaller craft and characterized by rapidly developing localized storms. The observations are inadequate in terms of numbers, frequency of updating and description of significant elements such as sea-state and sea surface temperature.

Civil

- Weather service offices currently providing limited marine services require additional staffing to assure that adequate forecasts and timely warnings are prepared and disseminated.
- Many meteorologists currently preparing marine forecasts require additional training in marine meteorology and physical oceanography to raise the quality of their products.

- Frequent and complete surface observations (including wave height) are urgently needed from inland lakes, rivers, dams, and reservoirs popular with the recreational boating community to form a sound base for forecasts and warnings for these locations.

- Communications support to disseminate information to users requires considerable expansion for the following reasons:

  a. Navy facsimile broadcasts are designed for specialized Naval uses, not for general civil use. The contents of these broadcasts may be changed to meet operational requirements. Adequate support to civil users requires that the products be responsive to their needs and the broadcasts compatible with their communications capability.

  b. Radiotelegraph broadcasts of meteorological information for high seas and offshore users are on a low or no priority basis since this service is generally provided free of charge. Vital information may not get to users under these arrangements.

  c. Radiotelephone broadcasts for high seas users are required more frequently and for longer periods to assure that necessary information will be available to users on a timely basis.

  d. Additional radiotelephone broadcasts are required for commercial fishing users. These broadcasts must have adequate power to reach the ships on the fishing grounds and they must also be made often enough to cope with rapidly changing weather conditions.

  e. Automatic Marine Telephone Answering Systems provided by the Department of Commerce are needed at many additional locations along coasts, lakes, and inland waterways so that more users may be serviced without major additions to the weather service offices and staffs.

Military

- Surface and upper-air observations from areas in which military operations are being conducted are inadequate.

- The need to conserve allocated radio frequencies by using multiplex techniques imposes technological disadvantages for vessels otherwise able to receive single-sideband high frequency environmental broadcasts (radioteletype and radiofacsimile).

- Slowness in adopting radiofacsimile recorder improvements within a system wherein several hundred potential users are affected by even minor changes constitutes a serious problem.

- There continues to be a shortage of trained personnel available.

- Surface and upper-air observations in the Southern Hemisphere and Arctic areas are inadequate.

Improvements Requiring Supporting Research and Development

- Suitable observing equipment is needed for obtaining the following measurements from shipboard and remote oceanic areas:

  a. Surface observations of wind, air temperature, sea level pressure, and moisture.

  b. Vertical profiles of wind, temperature and moisture.

  c. Spatial distribution of fog.

  d. Cloud conditions.

  e. Wave heights, periods and directions.

  f. Sea-surface temperatures.

  g. Solar radiation (remote oceanic areas only).

- Effective, reliable automatic weather observing and reporting systems are needed for use on ships, unmanned buoys and remote islands as well as at coastal locations.

- Improved processing techniques are needed for determining, from ship observations, the distribution of wind stress on the sea surface, the distribution of evaporation minus precipitation, and the net heat exchange across the sea surface.

- Improved forecasting techniques, including numerical methods, are needed for more accurate and longer range prediction of the following:

  a. Air temperature.

  b. Sea-surface temperature.

  c. Fog.

  d. Clouds.

  e. Sea state.

  f. Ice formation and movement.

  g. Precipitation patterns and amounts.

  h. Formation, intensification and motion of hurricanes and typhoons.

  i. Local winds.

5. PLANNED SERVICES AND PROGRAMS

The Department of Commerce plans a five-phase program to meet the applicable objectives of the Marine Resources and Engineering Development Act of 1966, and to improve services to civil marine users. This program includes a series of specialized products and distribution systems keyed to user requirements and communications capabilities. Before many of these products can be made available, additional resources must be committed. Descriptions of the Department of Commerce programs for the Marine Meteorological Service, plus selected Basic Meteorological Service programs of major significance to marine users, are discussed in the following paragraphs.

The planned products developed by geographic categories are described in Table 4. High seas products (Numbers 1 through 12 in Table 4) will cover the North Atlantic and North Pacific Ocean areas illustrated in Figure 7. Transmission of graphic products of facsimile broadcasts and alphanumeric products by radiotelegraph and radiotelephone broadcasts will be accomplished by use of leased transmitting facilities located in the vicinity of New York, San Francisco and Honolulu.

Offshore products, designed for users requiring frequent and detailed information will cover the areas illustrated in Figure 2. Because offshore users usually are not equipped to receive facsimile broadcasts, transmissions will be by radiotelegraph and radiotelephone. Increased use will be made of Coast Guard radio facilities to augment Department of Commerce and commercial radio stations in broadcasting offshore products.

Coastal, lake and inland waterways users constitute by far the most numerous consumer groups, and their activities are generally characterized by high sensitivity to adverse weather conditions. To provide services that will reach the greatest number of these users, the products must be in plain language and available to the user with simple and relatively inexpensive receiving equipment.

Products 16 through 25 in Table 4, as appropriate, will be made available utilizing the ESSA Weather Wire System, and VHF/FM radio transmitters operated by the Department of Commerce as part of the Basic Meteorological Service, automatic telephone answering systems of the Marine Meteorological Service, plus the cooperative efforts of Coast Guard and commercial radio and TV broadcasters. The order of priority for these services will be governed by the level of weather-sensitive marine activities in the particular area served.

Special commercial fishing products (Numbers 21 and 22 in Table 4) will be transmitted by commercial marine radiophone broadcasts augmented by appropriate Coast Guard broadcasts.

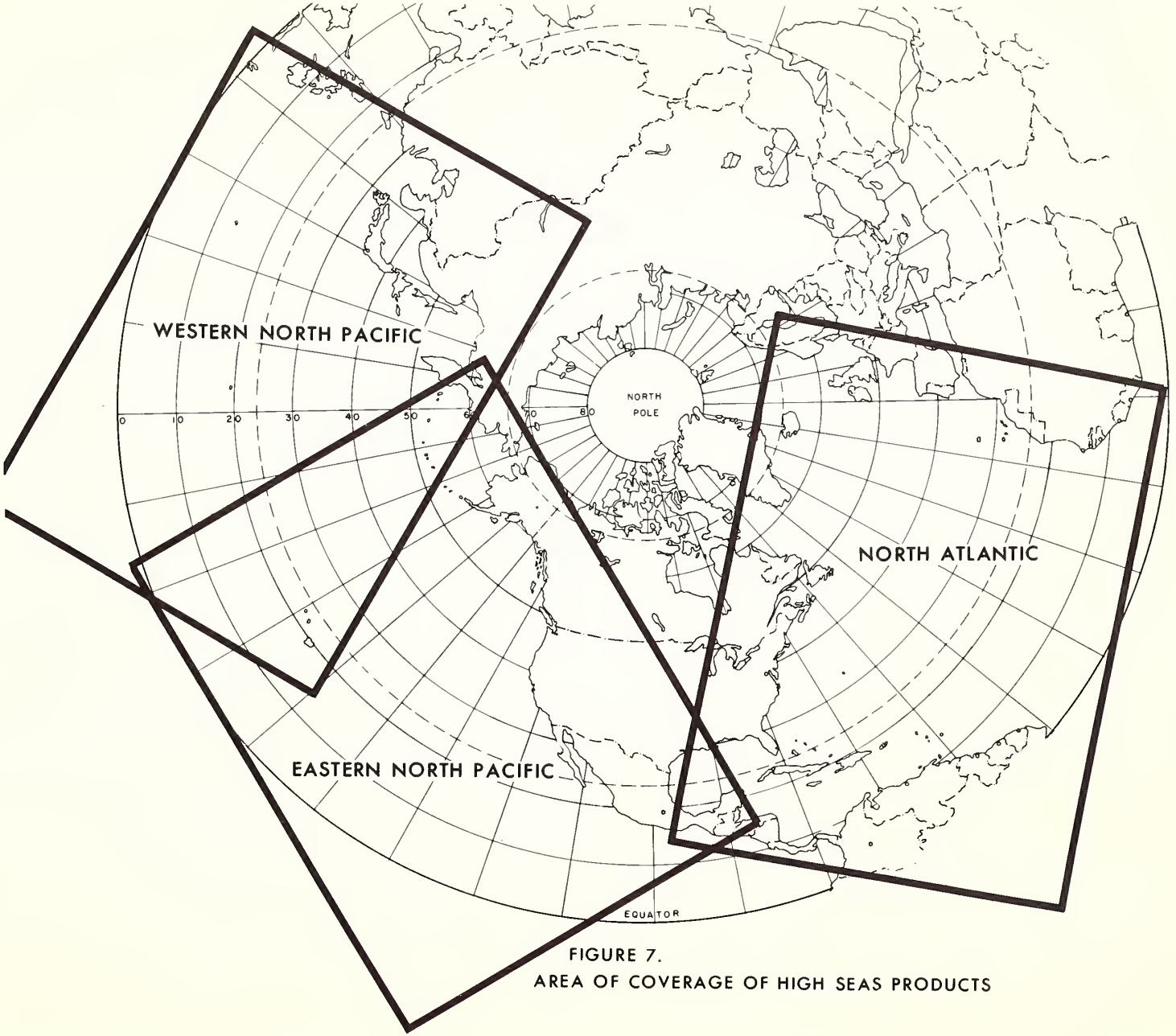

FIGURE 7.
AREA OF COVERAGE OF HIGH SEAS PRODUCTS

TABLE 4. CIVIL MARINE METEOROLOGICAL SERVICE OPERATIONAL PRODUCTS

PRODUCT NUMBER	SUBJECT AND FORM	CONTENT	VALID TIME(S)	CYCLE
1	High Seas Warnings (Alphanumeric via Facsimile)	Location and movement of pressure systems generating gale force and higher winds, including tropical storms and hurricanes, the extent of waves $\geq$ 2 meters, and other significant hazards.	24 hrs	6 hrs and as required
2	High Seas Marine Weather Analysis (Graphic)	Fronts, pressure centers, and isobars. Selected ocean station and moving ship observations including reports of wind, weather, visibility, temperature, sea temperature, and pressure.	Synoptic observation time	6 hrs
3	High Seas Wind Wave Analysis (Graphic)	Areas with waves $\geq$ 1 meter, $\geq$ 2 meters, etc. Areas of probable superstructure icing due to freezing rain or seaspray. Selected reports from ocean stations and moving ships concerning wave height, period, and direction.	Synoptic observation time	6 hrs
4	High Seas Marine Weather Forecast (Graphic)	Prognostic charts depicting the expected position of fronts and pressure centers at specific time intervals. Isobars to indicate intensity of centers and general wind flow. Forecast data concerning wind, temperature, sea temperature, and weather which causes visibility $\leq$ 1 mile at standard grid locations.	12, 24, 36, and 48 hrs	12 hrs
5	High Seas Wind Wave Forecast (Graphic)	Prognostic charts depicting the expected positions of fronts and tropical storms, and the areas in which waves $\geq$ 1 meter, $\geq$ 2 meters, etc. are expected, at specific time intervals. Areas of probable superstructure icing.	12, 24, 36, and 48 hrs	12 hrs
6	High Seas Extended Marine Weather Forecast (Graphic)	Prognostic charts (one per day at a specified time) depicting the expected positions of fronts and pressure centers, the intensity of the pressure centers, the areas in which winds $\geq$ 34 knots and waves $\geq$ 2 meters are expected, and the highest winds and wave heights expected in each area.	3rd, 4th, 5th and 6th day	24 hrs
7	High Seas Warnings (Alphanumeric and Voice)	See Product 1.		
8	High Seas Extratropical Marine Weather Forecast (Alphanumeric and Voice)	Location and intensity of pressure centers not described in warnings and expected direction and speed of movement. Description of frontal systems and expected movements. Identification of areas in which winds $\geq$ 20 knots, 30 knots, etc., and wave heights $\geq$ 2 meters, $\geq$ 4 meters, etc., are expected. Forecasts of temperature, sea temperature, visibilities $\leq$ 1 mile, and areas of superstructure icing.	48 hrs	6 hrs
9	High Seas Tropical Marine Weather Forecast (Alphanumeric and Voice)	Location and intensity of pressure centers not described in warnings and expected direction and speed of movement. Identification of areas in which winds $\geq$ 20 knots, $\geq$ 30 knots, etc., and wave heights $\geq$ 2 meters, $\geq$ 4 meters, etc., are expected. Forecasts of temperature, sea temperature, and visibilities $\leq$ 1 mile.	48 hrs	6 hrs

TABLE 4 (Continued)

PRODUCT NUMBER	SUBJECT AND FORM	CONTENT	VALID TIME(S)	CYCLE
10	High Seas Extended Marine Weather Forecast (Alphanumeric)	Location and intensity of pressure centers and movement of frontal systems. Identification of areas in which winds $\geq$ 34 knots and waves $\geq$ 2 meters are expected, and highest winds and waves.	3rd thru 6th day	24 hrs
11	High Seas Coded Analysis (Alphanumeric)	Surface weather and wind wave analysis coded in IAC (Fleet), including pressure centers, fronts, isobars, and two meter wave height contours, plus a listed selection of synoptic reports.	Synoptic observation time	6 hrs
12	High Seas Coded Forecast (Alphanumeric)	24 and 48 hour prognoses coded in IAC (Fleet) including pressure centers, fronts, isobars and two meter wave contours.	24 and 48 hrs	12 hrs
13	Offshore Warnings (Alphanumeric and Voice)	Location and movement of frontal systems or pressure centers from the coast to 250 miles seaward in designated offshore areas. Identification of areas in which winds $\geq$ 30 knots or waves $\geq$ 1 meter are expected.	24 hrs	6 hrs
14	Offshore Forecast (Alphanumeric and Voice)	Description of the general weather conditions and wind wave conditions expected in the offshore area. Includes temperature, sea temperature, cloudiness, type and intensity of precipitation, the distribution of winds $\geq$ 15 knots, $\geq$ 20 knots, etc., and wave heights $\geq$ 1 meter, $\geq$ 2 meters, etc., visibility when less than 5 miles, and areas of probable icing on superstructures or exposed equipment.	48 hrs	6 hrs
15	Offshore Observation (Alphanumeric and Voice)	Observations from selected stations.	Observation time	3 hrs
16	Seiche Warnings (Alphanumeric and Voice - Great Lakes)	Area of expected occurrence and expected change in height of water.	As required	As required
17	Coastal and Great Lakes Ice Forecast (Alphanumeric)	Description of areas of ice, identifying locations where ice is impassable or requires icebreaker assistance. General forecast of the formation or breakup of ice conditions on the Great Lakes, the interconnecting waterways, and the Alaskan coast, when applicable.	Week	24 hrs seasonal
18	Coastal Warnings* (Alphanumeric and Voice)	Significant changes in forecast wind, wave, or precipitation conditions, unusual tidal conditions, or heavy breakers and surf.	As required	As required
19	Coastal Forecast (Alphanumeric and Voice)	Description of the present and expected weather, winds, wave conditions, visibility, cloudiness, temperature, and precipitation along a designated strip of coastal water extending 15 miles seaward.	48 hrs	6 hrs
		* Combined with Product No. 19 in many cases.		

TABLE 4 (continued)

PRODUCT NUMBER	SUBJECT AND FORM	CONTENT	VALID TIME(S)	CYCLE
20	Harbor/ Anchorage Forecast (Alphanumeric and Voice)	Wind, wave, tide conditions and general weather forecasts of temperature, humidity, visibility, and any unusual effects of weather or wind waves on harbor or anchorage approaches.	48 hrs	6 hrs
21	Special Fishing Area Forecasts (Alphanumeric and Voice)	Location and movement of frontal systems or pressure centers through the fishing area. Identification of area with winds $\geq$ 15 knots, $\geq$ 20 knots, etc., or waves $\geq$ 1 meter, $\geq$ 2 meters, etc. Forecasts of temperatures to the nearest 5 degrees and water temperatures to 2 degrees. General description of cloudiness, visibility, and precipitation. (Also includes any available information on mixed layer depth.) **	48 hrs	6 hrs
22	Special Fishing Area Outlooks (Alphanumeric and Voice)	Location, movement, intensity, and change in intensity of pressure centers which will affect fishing area. Areas with waves $\geq$ 1 meter and highest waves expected. Areas with winds $\geq$ 30 knots and highest winds expected.	3rd, 4th, 5th and 6th day	24 hrs
23	Boating Outlook (Alphanumeric and Voice)	Areas in which waves $\geq$ 2 feet, winds $\geq$ 20 knots, or visibilities $\leq$ 1 mile are expected. Probability of precipitation, and expected temperatures.	3rd day	12 hrs
24	Breaker and Surf Forecast (Alphanumeric and Voice)	Height, period, and character of breakers and probable occurrence of dangerous surf conditions. Water temperature.	36 hrs	12 hrs
25	Inland Lakes and Waterways Warnings and Forecasts (Alphanumeric and Voice)	Weather, air and water temperature, waves and seiche conditions.	24 hrs	Variable 1-12 hrs

** Discussed in detail in the Federal Plan for Marine Physical Environment Prediction, April 1, 1968.

Department of Commerce Five-Phase Program

PHASE 1

- Establish Marine Forecast Centers at San Francisco and Washington.
- Expand the National Meteorological Center program to include sea and swell analyses and forecasts.
- Establish radio facsimile broadcasts from New York and San Francisco to distribute high seas products.
- Establish automatic telephone answering service at Miami, San Francisco, Anchorage, Cleveland, Houston, and Portland, Me. Figure 8 shows the existing and planned locations of these systems.
- Begin training meteorologists in physical oceanography through postgraduate and inhouse programs.
- Add a marine meteorologist to the ESSA-Weather Bureau staff to assist in program development and management.

PHASE 2

- Establish Marine Forecast Centers at Anchorage and Honolulu.
- Expand the National Meteorological Center to provide additional marine products, including sea surface temperatures.
- Establish radiotelegraph broadcasts on the East, West and Gulf Coasts; specific locations will be determined by the most effective and economical transmission arrangements.
- Establish automatic telephone answering service at Norfolk, Corpus Christi, Buffalo, Jacksonville, Mobile, New Orleans, and Charleston, S. C.
- Augment the service staff with a marine meteorologist at Norfolk, Seattle, and New Orleans.
- Expand the program to train meteorologists in physical oceanography to approximately double that of Phase 1. This level of training effort continues through Phases 3, 4 and 5.
- Establish quality control programs for marine products in the ESSA-Weather Bureau Eastern and Western Regions.
- Add a marine meteorologist to one ESSA-Weather Bureau regional staff.

FIGURE 8. EXISTING AND PLANNED LOCATIONS OF MARINE AUTOMATIC TELEPHONE ANSWERING SYSTEMS

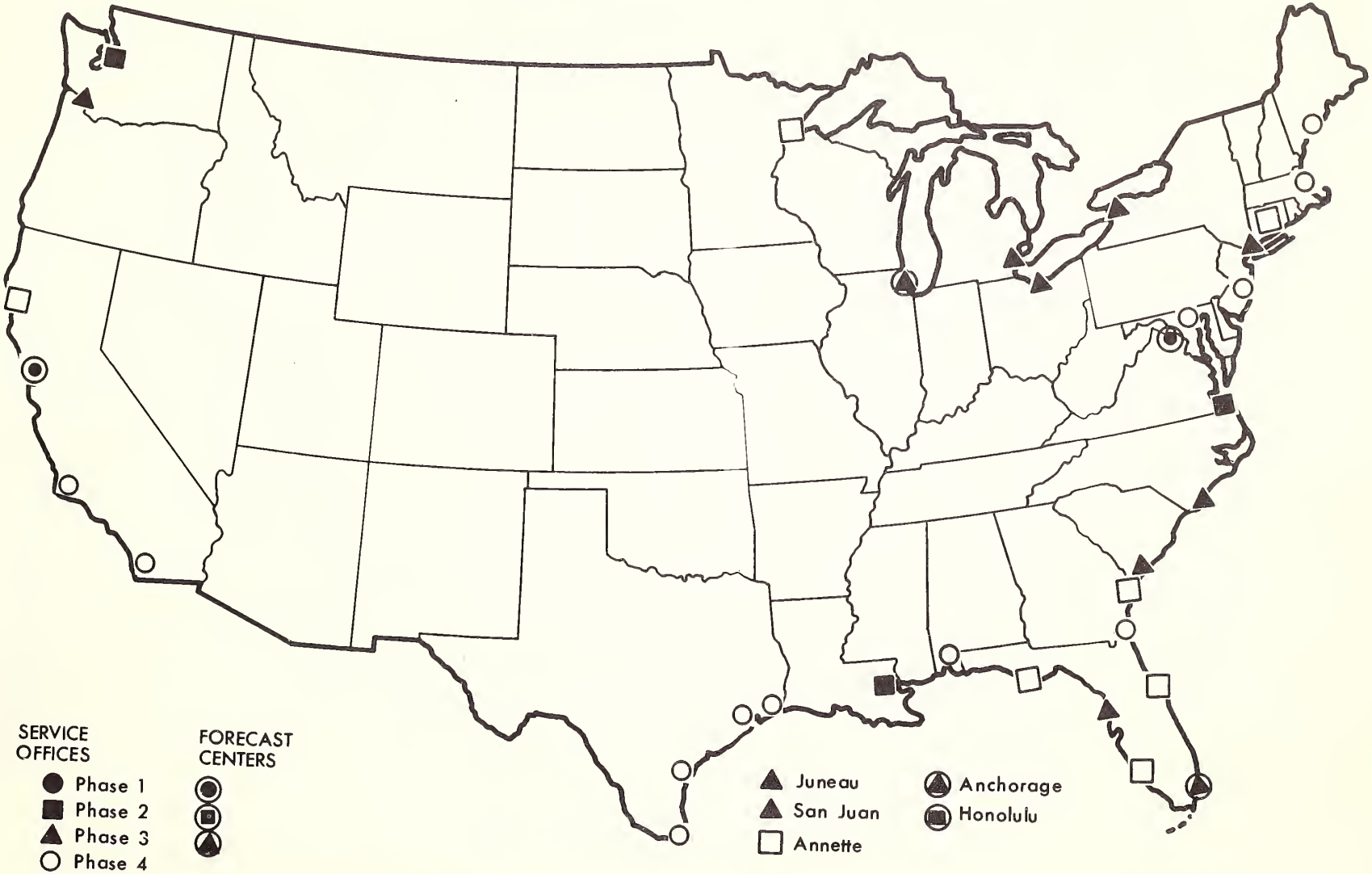

FIGURE 9. PHASED AUGMENTATION OF MARINE FORECAST CENTERS AND SERVICE OFFICES

PHASE 3

- Establish Marine Forecast Centers at Chicago and Miami.
- Expand the National Meteorological Center program to provide additional marine products, including mixed layer depths.*
- Establish a radio facsimile broadcast at Honolulu to distribute high seas products.
- Establish automatic telephone answering service at Astoria, Brownsville, Tampa, New York City, Detroit, San Juan, Portland, Ore., and Wilmington, N. C.
- Establish a radiotelephone broadcast at Boston to distribute products to commercial fishing users.
- Augment the forecasting staff with a marine meteorologist at Portland, Ore., Cleveland, Buffalo, New York City, Detroit, Juneau, San Juan, Tampa, Charleston, S. C., and Wilmington, N. C.
- Establish quality control programs for marine products in the ESSA-Weather Bureau Southern and Pacific Regions.
- Add a marine meteorologist to two ESSA-Weather Bureau regional staffs.

PHASE 4

- Establish radiotelephone broadcasts at Los Angeles, Miami and Anchorage to distribute products to commercial fishing users.
- Augment the forecasting staff with a marine meteorologist at Boston, Portland, Me., Jacksonville, Houston, Atlantic City, Corpus Christi, Baltimore, Brownsville, Port Arthur, Mobile, San Diego, and Santa Maria.
- Establish quality control programs for marine products in the ESSA-Weather Bureau Central and Alaskan Regions.
- Establish automatic telephone answering services at Atlantic City, Port Arthur, San Diego, and Santa Maria.

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* Discussed in detail in the Federal Plan for Marine Physical Environment Prediction, April 1, 1968.

PHASE 5

- Augment the forecasting staff by adding a marine meteorologist at Fort Myers, Eureka, Duluth, Savannah, Daytona Beach, Apalachicola, Annette Island, and Hartford.

- Establish automatic telephone answering services at Fort Myers, Eureka, Duluth, Savannah, Daytona Beach, Apalachicola, Ketchikan, and Hartford.

In addition to the foregoing 5-phase program for Marine Meteorological Services, the following improvements in the Basic Meteorological Service planned by the Department of Commerce will have major significance to marine users:

Observations

- The Cooperative Merchant Shipping Observing Progam will be expanded and improved by adding more ships and installing wind, sea surface temperature, and wave measuring equipment on selected vessels.

- The Cooperative Coast Observing Network will be expanded and modernized by establishing new stations, adding new equipment at some existing stations, and providing more frequent observations from selected stations.

- Automatic weather stations will be installed to provide observations from Coast Guard facilities and other locations where it is not feasible or economical to use cooperative observers.

- Telemetering equipment will be installed at selected coastal stations to obtain tidal data.

- The Basic Weather Radar Network will be expanded by adding radars along the New England coast and in the Pacific Northwest. A number of radars will also be added at inland locations to provide coverage for the Great Lakes and many smaller lakes and reservoirs.

Analyses and Forecasts

- Improved forecasts and warnings for tropical areas are expected from new machine products now under development at the National Meteorological Center.

- Machine produced 5-day or longer forecasts issued daily are planned by the National Meteorological Center. These forecasts are expected to be of considerable benefit to ship routing programs and planning by marine interests.

Communications

- The ESSA's Weather Wire System will be expanded to cover many of the areas not now served by this system.

- The VHF/FM radio broadcasts will be expanded as shown in Figure 5.

General Agency Support

- Maintenance programs for observing and communications equipment and quality control of merchant ship observations will be expanded.

Department of Transportation

The Coast Guard is reviewing its present radiotelegraph and radiotelephone marine weather broadcast schedules with the goal of making more frequent, more timely broadcasts of weather forecasts and warnings. Particular attention is being directed to the VHF/FM maritime mobile band, where Coast Guard VHF/FM facilities may supplement those of the Department of Commerce. The feasibility of making facsimile and other additional broadcasts will also be determined. The Coast Guard and ESSA-Weather Bureau are working together to improve the dissemination of weather information to marine users, especially the boating public.

Department of Defense

No major changes are planned in the military programs for the Marine Meteorological Service. There are, however, plans to expand selected ongoing programs. The more significant are:

- The use of computers in the Naval Weather Service Command will be increased to provide additional "tailored" support to military users.

- The Navy's Environmental Data Network will be extended to additional locations to speed the flow of observations, analyses and products to military users.

- The Fleet Multichannel Radioteletypewriter Broadcast System is currently being implemented and will be completely operational in the near future. However, to satisfy continuing needs of Allied Nations for marine meteorological information (and some Merchant Marine needs, until such time as the civil broadcasts are operational), the existing single channel radioteletype system will remain in operation from selected stations.

- A network of oceanographic/meteorological buoys (NOMAD's) may be established when equipment becomes operational.

- The Navy has a continuing program of modernizing its Meteorological/ Oceanographic Reconnaissance Aircraft.

6. PLANNED RESEARCH AND DEVELOPMENT

All of the work reported on herein is not primarily designed to satisfy the specific supporting research requirements that have been identified to improve the Marine Meteorological Service. Some of the effort discussed falls, for example, into the category of basic research; and other work has broader objectives than just the improvement of the Marine Meteorological Service.

The supporting research funded by ESSA that contributes to satisfying the Marine Meteorological Service requirements has been conducted principally, but not wholly, in support of the Basic Meteorological Service in consonance with the concept that civil programs for the Marine Meteorological Service will rely mainly upon the Basic Meteorological Service for general observational and forecasting support. Therefore, much of the ESSA funding for research is not attributed directly to the Marine Meteorological Service.

Analogously, the supporting research funded by the Navy that contributes to improvements is divided between funds attributable directly to the Marine Meteorological Service and certain research programs having the primary aim to improve the General Military and Ground Forces Support Meteorological Service.

ESSA and Navy are the only agencies that fund some research and development that is primarily aimed at improving the Marine Meteorological Service. A separate section describes related efforts by these two agencies as well as by others that should contribute to the improvement of the Marine Meteorological Service.

The improvements identified as requiring supporting research and development have been categorized as being either in the functional area of "observation" or in the area of "analyses and forecasts".

Observation

. Suitable observing equipment is needed for obtaining the following measurements from shipboard and remote oceanic areas:

a. Vertical profiles of wind, temperature and moisture

b. Spatial distribution of fog

c. Cloud conditions

d. Wave heights, periods and directions

e. Sea-surface temperatures

f. Solar radiation (remote oceanic areas only)

. Effective, reliable automatic weather observing and reporting systems are needed for use on ships, unmanned buoys and remote islands as well as at coastal locations.

Some of the improvements required in the observations category relate to the lack of a suitable, low-cost platform upon which sensors can be placed for use in the large expanse of oceanic and coastal areas. Although the sensors needed to observe and measure the weather parameters in the marine areas and those required in land areas are similar, problems inherent in the marine environment impose additional challenges to engineering to produce sensors that will operate efficiently for long periods of time in this particular environment. An alternative is the development of sensing devices which can observe the necessary parameters by remote means; this would alleviate some of the cost problem of procuring and logistically supporting the large numbers of sensing devices needed to observe effectively the phenomena of interest to the time-space scale desired.

Department of Commerce

The Department of Commerce (ESSA) plans to design a Marine Environmental Prediction System to deal with both the atmosphere and the oceans. Only that part which is concerned with marine weather services will be included in this Federal Plan.

On the basis of a recent field survey of user needs in marine weather services, and a preliminary survey of potential means for acquiring critical data in support of these services, a study of merchant ships (ships of opportunity) as observing platforms has been selected for special emphasis.

The merchant ship study will use computer programs to determine the optimum distribution of surface observations and upper air soundings that could be obtained from various numbers of suitably instrumented ships. Also, the effect of such factors as degree of automation, equipment portability, data preprocessing and communication will be analysed and evaluated in terms of cost and performance. Specifications for the various components of the shipboard observation system will be determined and suitable equipment then developed, particularly designed to operate in the marine environment.

Department of Defense

The Department of Defense (Navy) will continue to conduct research on all of the improvements required in observing except measuring solar radiation in oceanic areas by remote means.

Several efforts are directed toward improving techniques and equipment for obtaining meteorological data aboard naval vessels. Development of rocketsonde components is proceeding for use in obtaining soundings of wind, temperature, and moisture. The Navy's balloon-borne frost point radiosonde will undergo further development to provide greater reliability and accuracy in high level moisture measurements.

There is an extensive program planned to provide instrumentation and experimental techniques with accuracies and resolutions sufficient to describe the characteristics of a natural fog. This includes further development of the microwave hygrometers for measuring humidity, optical methods for measuring fog droplet size and number distribution, and new and improved instruments for measuring liquid water distribution, droplet and ice particle sizes and the number of nuclei.

A cloud height measuring device using a laser is being designed for use aboard ship. Also, improvements are being investigated for the shipboard readout equipment of automatic picture transmission from the National Operational Meteorological Satellite System.

In order to measure parameters which determine sea conditions, techniques are being investigated for objective measurements with radar. These techniques, if successful, would be used by ship and shore radars.

Sea-surface temperature measurements are now being made by a variety of equipment and techniques. Improvements are being sought by standardizing the methods to achieve needed accuracy and comparable measurements.

The National Bureau of Standards is developing devices for visibility measurements for the Navy; for shipboard use, a back-scattering measuring device is being tested. This device does not require a long baseline as does a transmissometer; it may be used as a sensor in the Navy's Shipboard Automatic Weather System.

The system is under development to provide observations on ships where no observers are available. Sensors are being adapted or fabricated for use in a small unit. Inputs from standard equipment currently in use on shipboard will be integrated into the device, if feasible.

Because weather reconnaissance aircraft currently provide one of the best means of acquiring information from remote oceanic regions, efforts are underway to improve their capability to obtain data above and below flight level. The 2.75 inch folding-fin aircraft rocket motor is being evaluated for use in a vertical sounding system; prototype models of system components are being developed and evaluated. Also, an aircraft-borne turbidity sensor is being developed for use in the study of atmospheric contaminants, as they relate to changes in visibility. In addition, a radiation thermometer is undergoing test and evaluation.

Several approaches are being used in developing automatic weather observing systems for use at unmanned sea and coastal locations. To support naval operations in oceanic regions other than polar, the Navy Oceanographic/ Meteorological Automatic Device (NOMAD) is being developed. The NOMAD senses synoptic oceanographic and meteorological data, processes the data and transmits it to receiving locations. It is intended to operate for prolonged periods in deep water anchoring sites. Smaller NOMAD buoys (1/2 scale) are also being developed and evaluated. The Polar Automatic Weather Station (PAWS) was developed and is being improved for use in polar areas. Sensors and telemetry equipment suitable for normal climatic conditions will fail in the polar environment; improvements and adaption of these equipments are being accomplished. New sensor development will be undertaken where necessary. The third development of automatic stations is the Tactical Island and Marine Device. The approach here is to adapt, standardize, improve and, where necessary, develop sensor systems for measuring environmental parameters in remote areas during tactical situations. Emphasis is on development of solid state electronics for command control and automatic storage of observations. Development of ocean-wave sensors and pretransmission processing of ocean-wave data is underway and will continue. Wave height and period sensing devices are being investigated for possible development for operational use.

Analyses and Forecasts

. Improved processing techniques are needed for determining, from ship observations, the distribution of wind stress on the sea surface, the distribution of evaporation minus precipitation, and the net heat exchange across the sea surface.

. Improved forecasting techniques, including numerical methods, are needed for more accurate prediction of the following:

a. Air temperature

b. Sea-surface temperature

c. Fog

d. Clouds

e. Sea state

f. Ice formation and movement

g. Precipitation patterns and amounts

h. Formation, intensification and motion of hurricanes and typhoons

i. Local winds

Inadequacies in the analysis and forecasting functional area can be traced in some degree to the inadequate observations used to define the initial state in marine areas. An improvement in the density and frequency of observations in the sparse areas should result in increased forecasting capability. As in the case of the improvements required in observing, some of the improvements needed in analysis and forecasting related for marine needs are much the same as for land areas. Therefore, resolving existing common analysis and forecasting problems for land areas will result in improvements of marine area forecasts.

Department of Commerce

ESSA is funding research aimed at improvements relating to the forecast of sea state. A machine program is being prepared to accomplish the analysis and forecast of wind waves and the resulting swell, making use of computed surface winds and other information available at the National Meteorological Center. The program is based on physical models of the generation, movement, and modification of waves used by the Navy at the Fleet Numerical Weather Facility.

Objective techniques are being developed and tested for forecasting wind-induced changes in water level on Lake Erie. On a shallow lake such as Lake Erie, sustained winds can result in damaging floods.

Techniques will be developed and tested for predicting storm surge from extra-tropical storms and hurricanes. These predictions will be derived from multiple-regression equations using numerical forecasts of sea level pressure at selected grid points.

Techniques for forecasting surf and breakers and other near-shore phenomena will be developed.

Some research effort will be devoted to developing techniques for predicting sea temperature structures.* ESSA will also begin development of techniques for predicting ice formation and break-up over inland waters.

Department of Defense

The scope of the research activities of the Navy encompasses all of the desired analysis and forecasting improvements identified as requiring supporting research.

Considerable effort is being devoted to the development of numerical models and techniques applicable to naval environmental forecasting problems. Specific problems include:

- Improving analysis and forecasting techniques for polar regions;
- Development and evaluation of meteorological aids such as computers, scales, rules, tables, etc., for naval operational units;
- Preparation of a handbook of forecasting procedures and techniques;
- Investigation of development, changes in intensity and movement of middle latitude maritime weather systems in order to develop better forecasting techniques;
- Development of summary maps and models of the atmosphere above the troposphere to improve analysis and forecasting techniques and to ascertain the effects of upper air level changes on tropospheric weather;
- Investigation of ballistic density and temperature for updating the Navy Meteorological Ballistic Manual;
- Investigation of the relationship between measurements of atmospheric electricity and fog formation or dissipation in order to develop techniques that will improve short-range fog forecasting;
- Evaluation of meteorological satellite products and adaption for Navy use; and
- Development of techniques to predict tropical storm development, change in intensity and movements.

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* Discussed in detail in the Federal Plan for Marine Physical Environment Prediction, April 1, 1968.

Exploration by computer models of heat, water, and energy processes will continue. Programs which provide rudimentary computations of sea-air energy exchange are presently operational; studies of air-ocean interaction in stable weather systems will continue with the aim to refine the programs. Studies of hurricane wind effects on the thermal structure of the sea-surface layer will continue.

Numerical methods have received special attention during recent years. Future efforts are directed toward:

- Improving the accuracy of prediction of the distribution of atmospheric/oceanographic elements and the processes changing them.
- Developing and implementing an operational tropical forecasting model (non-storm) utilizing data derived from satellite cloud readout information in addition to all available conventional data.
- Point forecasting of standard oceanographic/atmospheric parameters 24-36 hours in advance.
- Developing water distribution analysis and forecast models, operational simplified cloud and precipitation forecasts and improving fog forecasts through refined moisture modeling.
- Improving existing typhoon/hurricane steering models.

A large portion of the research effort at the Navy Weather Research Facility is now directed toward tropical forecast problems, especially formation and intensification of tropical cyclones. Computer models are also being developed for prediction of cloud and fog development and dissipation.

Summary of Planned Research Efforts

The current and planned research efforts of ESSA and Navy in support of the Marine Meteorological Service are summarized to show the phased efforts.

ESSA Five-Phase Program

Phase 1

- Design and develop a merchant ship traffic analysis model
- Conduct study of concepts for acquiring meteorological and oceanographic data from merchant ships
- Develop computer programs for prediction of surface wave heights
- Collect data on extratropical storm surges
- Develop and test techniques for predicting wind-induced tides

Phase 2

- Complete design study of merchant ship data acquisition system
- Initiate system engineering study for merchant ship data acquisition system
- Improve the open ocean wind-wave operational forecasting program
- Complete development of program for predicting open ocean swells and initiate test
- Complete development of techniques for predicting wind-induced tides
- Initiate development of multiple regression equations for predicting storm surges
- Initiate development of prediction techniques for wind waves in coastal waters
- Initiate development of current sensors

Phase 3

- Complete the system engineering study for merchant ship data acquisition system
- Continue development of prediction techniques for waves, swell, storm surges, breakers and surf along coasts
- Develop wind and humidity sensors to withstand the marine environment on merchant ships

Phase 4

- Test techniques for predicting storm surges
- Test techniques for predicting coastal winds
- Initiate development of improved techniques for predicting sea temperature structure
- Initiate development of sea-state sensors
- Initiate test and evaluation of Marine Environmental Prediction System weather equipments and observation techniques

Phase 5

- Prepare computer program for prediction of storm surges
- Initiate development of techniques for predicting hurricane storm surge
- Develop improved techniques for predicting sea surface temperature
- Initiate development of techniques for predicting ice formation and break-up
- Continue test and evaluation of Marine Environmental Prediction System weather equipments and observation techniques

Navy Program

No major changes are planned in the military programs for supporting research and development to improve the Marine Meteorological Service. It is planned to continue the following ongoing programs:

- Improvement and development of buoy systems at unmanned sea/coastal locations
- Development and implementation of an operational tropical forecasting model (non-storm)
- Development of techniques for point forecasting of atmospheric parameters 24-36 hours in advance
- Development of simplified cloud and precipitation forecast techniques
- Refining moisture modeling for improving fog forecasts
- Improving typhoon and hurricane steering models
- Conducting studies on formation and intensification of tropical cyclones
- Shipboard upper-air and surface sensing devices

7. RELATED RESEARCH EFFORTS

A number of studies and experiments are being conducted by educational institutions under the support of the National Science Foundation, the results of which, though not aimed at direct support of the Marine Meteorological Service, will assist indirectly in solving some of the technical problems.

Line Islands Experiment

One group of these studies was a part of the Line Islands Experiment in the tropical regions of the Pacific Ocean. Aircraft observations were made as follows:

- Time-lapse motion pictures of clouds;
- Radar photographs of precipitation areas;
- Wind measurements;
- Temperature and moisture vertical profile measurements;
- Infrared measurements of sea-surface and island temperatures;
- Short wave solar radiation measurements;
- Aerosol count; and
- Infrared measurements of atmospheric water vapor.

These observations will be used for a number of studies, including:

- Study of atmospheric motions, structure and physical processes operating in the equatorial convergence zone;
- Effect of atolls on oceanic currents;
- Interaction between the ocean surface and the overlying atmosphere;
- Synoptic and subsynoptic weather processes in the tropical region;
- Investigations of ocean-atmospheric momentum exchange, Lagrangian dynamics and atmospheric tides; and
- Sea-surface and subcloud layer temperature gradients in the vicinity of the intertropical convergence zone.

World Weather Program

Several Federal agencies are planning to support the World Weather Program which consists of the World Weather Watch (WWW) and the Global Atmospheric Research Program (GARP). The WWW will be a system for observing, communicating, and processing global weather data adequate to meet the needs of the nations of the world. Implementing the global system will require complex system design activities, considerable technological development and a full-scale research program.

Extending the time range of marine environmental prediction is an essential goal of the service improvement program. This is an integral part of the larger problem of long range meteorological predictions. The international scientific community, through International Council for Scientific Unions (ICSU) and WMO, have joined together to plan GARP which will conduct basic research into the dynamics of the atmosphere with the objective of extending the time range of forecasts. This program will be concerned with the total atmosphere - continental as well as marine.

A number of comprehensive field experiments will be required in the pursuit of GARP. The first of these will be the Barbados Oceanographic and Meteorological Experiment (BOMEX), an experiment being planned and organized by the United States, to be carried out in the vicinity of the Island of Barbados in the spring of 1969.

The primary focus of BOMEX is on the problem of ocean-atmosphere interaction. The specific boundary layer research objectives include studies of:

- The flux of momentum, radioactivity, aerosols and energy (radiative, sensible and latent heat) at the interface and their divergence and transformations in the interior of each fluid;

- The response of the atmosphere - ocean system to variations in boundary conditions; and

- The feasibility of parameterizing the area-wide integral of at least the surface fluxes from observation at the fixed corners or perimeters.

Research in the preceding areas will provide essential ingredients in the refinement of the mathematical models of the atmosphere - a prerequisite to extending the time range of forecasts - and will provide valuable experience for follow-on and larger experiments in the future.

A number of Federal agencies, universities, and the National Center for Atmospheric Research (NCAR) are participating in this experiment. A BOMEX Project Office has been established in the Office of World Weather Systems, ESSA, to provide a focus for the design and planning of the total experiment.

The largest and most complex of the projects being planned under GARP is the Global Meteorological Experiment (GLOMEX). Both the establishment of the WWW and the conduct of GLOMEX involve difficult system design and integration problems. The United States will participate in appropriate design studies. This activity includes cost/performance analyses of alternative configurations, further evaluation of potential of new techniques, formulation of new processing techniques, subsystem and system design for both the WWW and GLOMEX. The planned United States effort, principally by NASA and the Department of Commerce, falls into five areas:

- Overall systems design and integration studies (Commerce);
- Global observation system design (Commerce);
- Global telecommunications system design (Commerce);
- Global data processing system design (Commerce); and
- Satellite system feasibility and design studies (NASA).

Achievement of the long-range objectives of the WWW depends heavily on development of new observation and communication techniques. Although present technology is capable of providing the observations and communications required, the new technology, which includes balloons, buoys and satellites for remote sensing, communications and data collection, offers promise of reducing the cost of the World Weather Watch and GLOMEX in comparison with costs associated with present technology.

Meteorological Satellite Applications

Much of the meteorological satellite development effort will have a major impact on the Marine Meteorological Service. Satellite remote sensing instrumentation offers promise of being the most effective and economical technique for observing cloud distribution and vertical profiles of temperature, water vapor and ozone over oceanic areas. Development of sensors to accomplish these observations includes infrared radiometers and spectrometers, microwave techniques, lasers and ultra-violet devices. Some of these developments are further advanced than others and may be integrated into the WWW and GLOMEX in the early 1970's. The final configuration of remote sensors for use in an operational satellite system will be dependent upon a test flight program and evaluation of data received from the competing sensors. Satellites are required to flight test remote sensors and other equipment. Nimbus B, D, E, and F and the Applications Technology Satellites (ATS) provide the required test beds. Early versions of remote sensors will be tested on Nimbus B and development of advanced models will continue.

A conceptual system study of the WWW has indicated that satellites offer the most efficient and least cost, long-range approach for carrying out the functions of the Global Telecommunications System. Communication feasibility tests, continued experimentation, and new communications techniques and transmission and receiving equipment will be necessary before a fully satisfactory spacecraft can be achieved. A test will be conducted on ATS-3 and further studies will be undertaken.

The concept of obtaining atmospheric measurements through the use of satellites to interrogate and locate measuring devices mounted on earth, ocean, or atmospheric platforms offers great promise for the WWW and GLOMEX. Three satellite data location and collection (DATALOCOL) systems are now under development. These include Interrogating, Recording, Locating System (IRLS), Omega Positioning and Locating Equipment (OPLE), and EOLE, a French system. The United States is cooperating in the test of EOLE. After evaluation of the results of system tests, a preoperational DATALOCOL system will be designed and fabricated. Initial models of IRLS I and OPLE I systems will be tested during FY-68 and development will continue on advanced versions.

Other Applications

Other related efforts by ESSA include the development of a windfinding system for use on merchant ships. An attempt is being made to develop an automatic antenna system which does not require the highly sophisticated tracking system used on land. Further, ESSA is engaged in a two-phased buoy development program. The first phase will determine operational, equipment and total system requirements. The second effort is to develop and test three prototype satellite-interrogated buoys to determine sea-keeping and communications capabilities. The results of these two programs will determine total hardware requirements.

Studies are also being made of the atmospheric effects on the dynamics of the circulation in the Great Lakes and in the San Francisco Bay area.

Other research efforts include the development of an airborne radiometer for use not only in measuring sea-surface temperature, but also in making a heat budget study of the sea-surface and the development of a capability for making reasonably accurate measurements of vertical turbulent flux.

The Department of Transportation (Coast Guard) is programing a large effort in marine sciences for FY-69. Although this is a related program which will benefit meteorology, the program funding is carried entirely in the marine sciences area. This effort is a research and development, test and evaluation program leading to a national data buoy system. Since the most serious deficiency in the available information on data buoys is the lack of knowledge on their reliability and survivability, the plan is to:

- Establish an operational test system of buoys in the natural environment using readily available equipment to test for reliability and survivability;

- Carry on a research and development phase to establish a five-year state-of-the-art position; and

- Establish a modest program for looking at future possible technological breakthroughs.

The capability to make meteorological observations from these buoys is an integral part of the program.